Center Independent Research & Development: GSFC IRAD

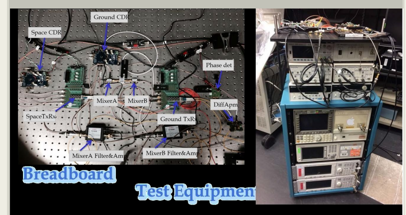
High Precision RF Ranging and Range Rate Measurements over Laser Communication in Cubesat Platform (Ranging over optical carrier)

Completed Technology Project (2015 - 2016)

Project Introduction

We propose to experimentally demonstrate high precision ranging (<1 um) and range rate (<1um/s) measurements using RF modulation on a optical carrier that is conducive to use on a laser communication channel. This is a continuation and further improvement of last year's CIF/IRAD "Miniature Laser Communication with Ranging, Range rate capabilities" which has achieved 20 micron ranging and 10 micron/s range-rate accuracy.

This IRAD will focus on the following methods to achieve higher measurement accuracies:
1. Improve the instrument signal noise ratio by adopting: an ultra-low phase noise clock source; low noise active components, and applying different modulation formats on optical carrier. 2. Improve test equipment sensitivity: by developing a Dual Mixer Time Difference (DMTD) time/frequency test apparatus, and developing a clock cleanup phase-locked-loop (PLL) with an ultra-low phase-noise Oven-Controlled-Crystal-Oscillator (OCXO).
The realization of sub-micron ranging and range rate capability in a small-sat platform will: Advance the state-of-the-art for optical communication systems by including the accurate optimetric observations; Enable precision formation flying missions that include virtual sensors, sensor webs, large-number-multi-spacecraft distributed mission, autonomous rendezvous & docking; serve as an enabler for gravitational-based small-sat scientific missions; and provide the essential building blocks for "Strategy and Implementation Distributed Spacecraft Missions (DSM)"
Ranging and range rate measurements can be derived from an optical communication data link clock signal. In any synchronized communication system, data is always synchronized to a clock signal. The comparison of receiver and transmitter clocks provides the accurate ranging and range rate measurements. This system can be configured in either a "one way" or "two way" mode.
In a the two-way mode, the clock is looped back at the spacecraft and the measurement is done on the ground station by comparing the received signal to a high precision transmit clock. This provides very high accurate measurements since the frequency measurement is conducted against its-own source.
In the "one way" mode, both transmit and receive spacecraft have their own precision on-board clock sources. The received clocks are measured against the on-board high-precision clock. The resulting frequency measurement provides two outputs: the transmit and receive clock source frequency difference, and the Doppler shift due to the spacecraft movement. They can be expressed as:
Space frequency measurement: $\delta fspace = fspace - (fground+\delta fdoppler)$
Ground frequency measurement: $\delta fground = fground - (fspace+\delta fdoppler)$
The Doppler frequency and ground-space clock offset can be calculated as:
The sum of these two frequencies gives Doppler shift
$\delta fspace + \delta fground = -2\delta fDoppler$



Ranging over Optical

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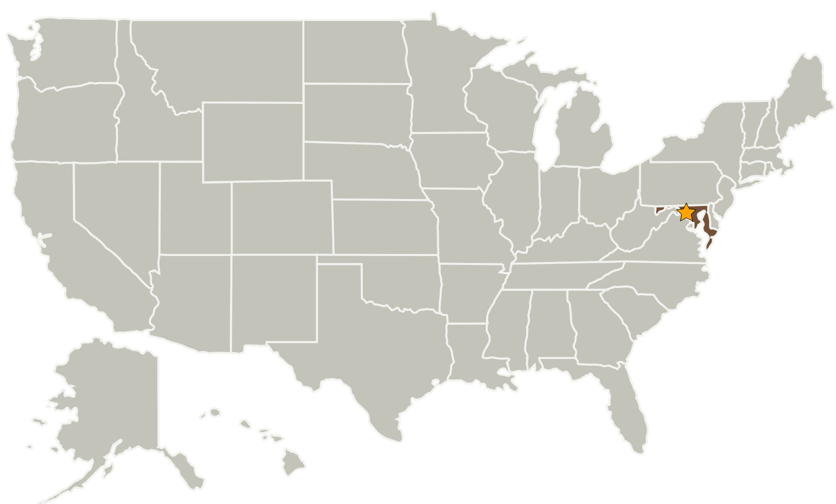
The Difference of these two frequencies gives ground and space oscillator frequency offset
δfspace - δfground = -2(fspace - fground)
The frequency offset measurement from "one-way" configuration is extremely useful for deep-space missions to calibrate the on-board clock source.
The work for this year will focus on improving accuracy to less than 1 micron/s and 1 micron distance. The prototype instrument will be compatible with a Cubesat form factor.

Anticipated Benefits

Provide precision optimetric measurement with optical communication links

Provide precision ranging and range rate for science based instrumentation

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
★Goddard Space Flight Center(GSFC)	Lead Organization	NASA Center	Greenbelt, Maryland

Primary U.S. Work Locations
Maryland

Organizational Responsibility

Responsible Mission Directorate:

Mission Support Directorate (MSD)

Lead Center / Facility:

Goddard Space Flight Center (GSFC)

Responsible Program:

Center Independent Research & Development: GSFC IRAD

Project Management

Program Manager:

Peter M Hughes

Project Managers:

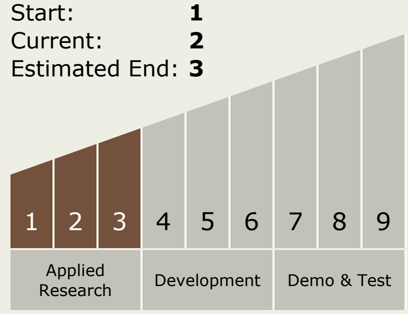
Terence A Doiron
Dennis W Woodfork

Principal Investigator:

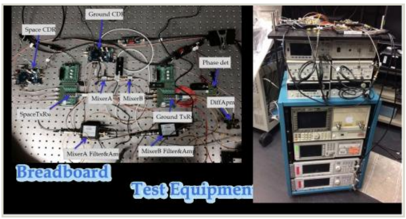
Guangning Yang

Technology Maturity (TRL)

Start: **1**
Current: **2**
Estimated End: **3**



Images



Ranging over Optical
Ranging over Optical
(https://techport.nasa.gov/image/19302)

Project Website:

http://aetd.gsfc.nasa.gov/

Technology Areas

Primary:

- TX05 Communications, Navigation, and Orbital Debris Tracking and Characterization Systems
  - └ TX05.1 Optical Communications
    - └ TX05.1.6 Optimetrics